Projecting Effects of Climate Change on River Habitats and Salmonid Fishes:

Integrating Remote Sensing, Genomics, and Demography to Inform Conservation

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Purpose and Need

Salmonids (salmon and trout)

- Keystone species for ecological, economic, and cultural systems
- Many species are in decline as a result of habitat loss, harvest, invasive species, and fish hatcheries (Lichatowich 2001, Quinn 2005, Muhlfeld et al. in press)
- All species are sensitive to changes in stream flows and temperature (because ectothermic) (Schindler et al. 2003, Quinn 2005, Naiman et al. 2009, Morris and Stanford 2011)

Figure 1. Bull trout (*Salvelinus confluentus*) are highly sensitive to climate change, requiring some of the coldest water habitats of all salmonids. Like most trout, bulls are non-anadromous (remain in freshwater throughout their lives).

Figure 2. Chinook salmon (*Oncorhynchus tshawytscha*) are the largest salmon (weighing >130 lbs.) and one of the key species in salmon fisheries. Chinook, like most other salmon, are anadromous, spending most of its life in the open ocean.

Climate Change

- Conservative projections of climate change over the next 100 years suggest regional warming of 3-5°C and precipitation changes of up to 20%, with particular impacts to timing of stream flow peaks and lows (IPCC AR4)

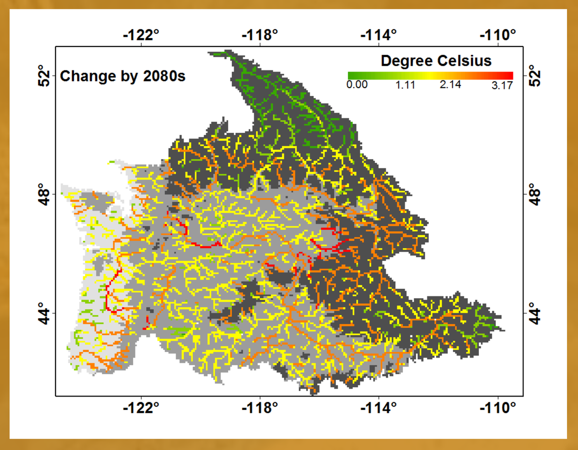

Figure 3. Projected increases in stream temperature across the Pacific Northwest by the 2080s (Wu et al. 2012)

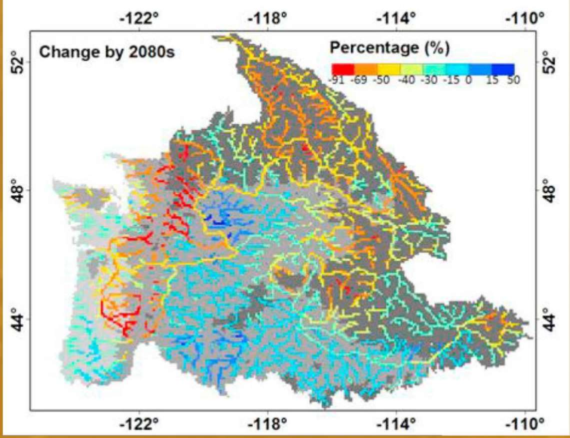

Figure 4. Projected changes in mean summer stream flow across the Pacific Northwest by the 2080s (Wu et al. 2012)

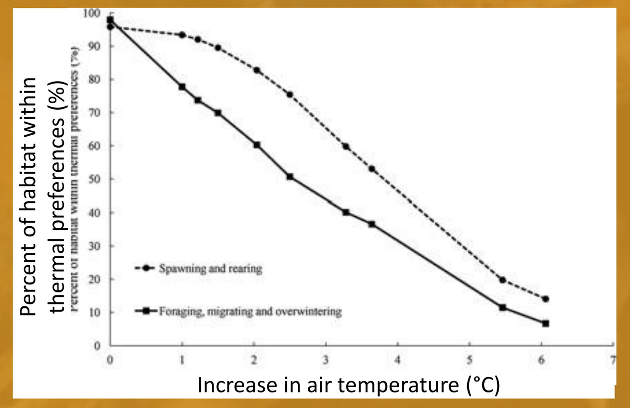

Figure 5. Scenarios of climate change may reduce available habitat for salmonids (here, for bull trout; Jones et al. 2013)

Improving Decision Making for Conservation Management

Need

- Organizations need to prioritize stream segments, populations, and types of conservation actions (e.g., monitoring, habitat restoration, reduced harvest quotas) to manage salmonids under a changing climate
- Current decisions often are made using incomplete data, non-replicable methods, and inadequate understanding of uncertainty (Hand et al. in prep)
- Population vulnerability (i.e., risk) analyses (VA) are needed but robust Decision Support System (DSS) and tools are lacking
- Remote sensing and landscape genomics offer enormous untapped potential and should be integrated (with ecology and demography) to facilitate conservation decision making (Schwartz et al. 2009, Whited et al. 2013, Hand et al. in prep, Kovach et al. in prep)

Solution

- Develop the Riverscape Analysis Project (RAP; Whited et al. 2013) into a DSS to provide conceptual understanding, methodological guidelines, easy data access, and web tools for aquatic species (salmonids), riverscape demo-genetic connectivity, and climate change VA

Figure 6. RAP data extraction tool allows habitat complexity metrics to be extracted for any sub-watershed.

Vulnerability Assessment Guidelines to Help Decision Makers

- Conceptual framework and understanding of VA
- Guidelines on necessary elements to improve comparability and robustness of results
  - Conceptual modeling of ecological system and climate stressors
  - Types of data and their potential use in conducting VA where vulnerability = f(exposure, sensitivity, adaptive capacity); emphasis on integration of remote sensing and genomics data and approaches (Luikart et al. 2003, Schwartz et al. 2009)
  - Exploration of multiple extents and resolutions of fish population structure and data representations
  - Explicit consideration of life stages, life histories, and habitat connectivity
  - Assessment of sensitivity and uncertainty of data and methods

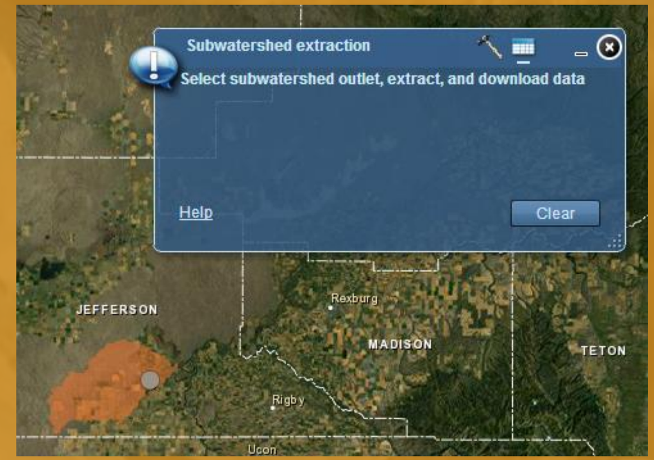

Figure 7. RAP data extraction tool allows habitat complexity metrics to be extracted for any sub-watershed.

Easy Access to Data

- Baseline climate data and scenario projections
- Map-based links to available genetic and demographic data
- Remotely sensed metrics for habitat quality and complexity and spatio-temporal habitat availability (freeze-thaw dynamics and water inundation timing)

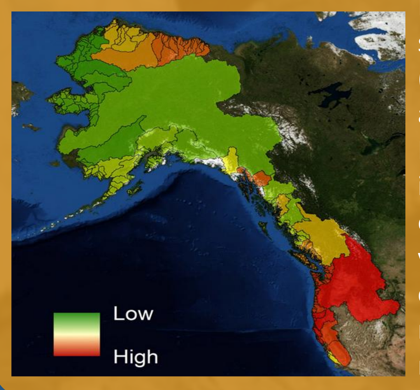

Figure 8. Chinook salmon stress index (2080s) currently available on the RAP web site illustrating an elementary tool to visualize combined climate and habitat related vulnerability metrics.

Vulnerability Analysis Web Tool

- Web-based tools to integrate RAP and user-provided data into VA incorporating necessary components
- Worked examples of VA and connectivity modeling (Fig. 9, Hand et al. in prep; Fig. 10, Kovach et al. in prep)

Riverscape Genetics Web Tool

- Genetic/genomic data are increasingly available to help predict species' adaptive capacity and riverscape population connectivity (gene flow and dispersal)
- Web-based tool to integrate RAP and user-provided demographic and genetic data to investigate specific relationships between climatic variables and local- and meta-population responses (adaptive potential, connectivity)
- Riverscape genetics tools can streamline the acquisition, visualization and analysis of genetic data to greatly aid future conservation planning and research.

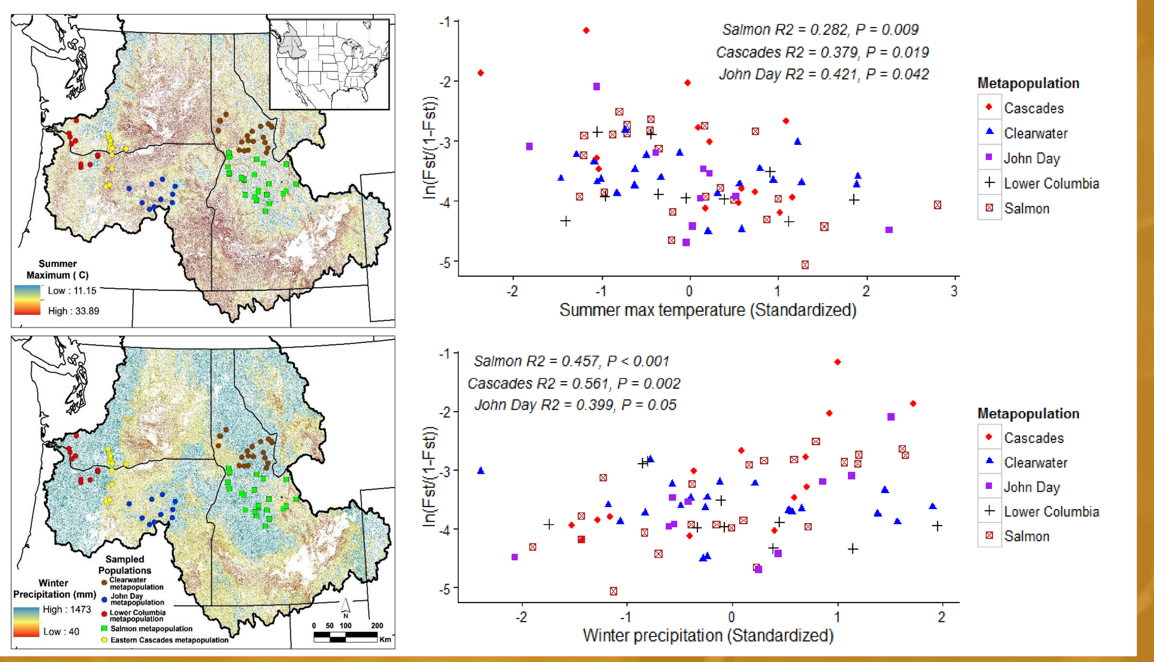

Figure 9. Steelhead genetic data was highly correlated with winter precipitation and summer max temperature for metapopulations in the Columbia River Basin. Monitoring gene flow and adaptive capacity can greatly inform our understanding of the impacts of climate on genetic diversity, connectivity, and future threats to salmonids (Hand et al. in prep)

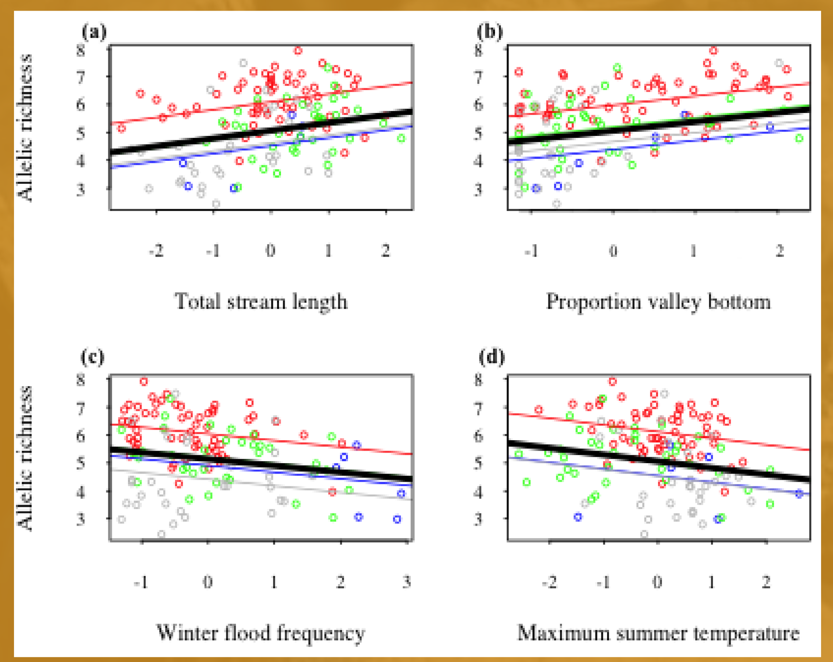

Figure 10. Current project work is illuminating the relationship between genetic diversity (allelic richness) and easily measured (e.g., remote sensed) habitat metrics, potentially allowing the projection of genetic diversity across space and time for use in vulnerability assessments (Kovach et al., in prep)

Progress To Date

- Workshop gathering 16 leaders in salmonid genetic, demographic, and habitat modeling held to discuss integrating demo-genetics with salmonid vulnerability models
- Modeling efforts discover surprisingly strong relationships between climatic and genetic variables (Kovach et al. in prep, Hand et al. in prep)
- Developed and applied a novel demo-genetic modeling approach to bull trout (Landguth et al. 2014)
- Survey sent to 25 potential end-users requesting information on their DSS and primary data needs
- Remotely sensed data on flood inundation and freeze thaw cycles being added to RAP (Fig. 11)
- Genetic data being gathered from labs and scientists across the nation

Figure 11. Freeze/ Thaw data extraction tool allows Freeze/Thaw metrics to be extracted for any sub-watershed.

Next Steps

- Practitioner guide for minimum required components of VA
- Worked examples of vulnerability components/assessments in collaboration with end-users
- Development of web-based tools with, and for, end users
- Quantify how our tools improve decision making and conservation

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